CARBON DIOXIDE EXTINGUISHING SYSTEMS

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1.0 SCOPE

FM has accepted and adopted NFPA 12, *Standard for Carbon Dioxide Extinguishing Systems*, 2000 Edition. FM comments including any differences between the NFPA and FM are provided in the FM Interpretation Section.

This data sheet provides general information on carbon dioxide extinguishing systems including guidelines for their use, design, installation, testing and maintenance. FM Property Loss Prevention Data Sheet 4-0, *Special Protection Systems*, also applies to carbon dioxide extinguishing systems.

1.1 Changes

January 2013. Minor editorial changes were made for this revision.

2.0 FM INTERPRETATION

2.1 Introduction

Design, install, test and maintain carbon dioxide extinguishing systems in accordance with NFPA 12, *Standard for Carbon Dioxide Extinguishing Systems*, 2000 Edition. In its application, use the following interpretations.

2.1.1 Shall versus Should

In most if not all instances, the widespread use in the text of the mandatory ''shall'', within the NFPA Standard, can be replaced by the more permissive ''should''. This is in keeping with other FM standards.

2.1.2 Authority Having Jurisdiction (AHJ)

There are many references in the NFPA Standard to the term AHJ. Legally this could mean the state fire marshal, the local fire department, or some other state or municipal office. In the application of this data sheet, the reference is solely to FM unless the legal authority takes precedence.

2.1.3 Related NFPA Standards

There may be a number of references to other NFPA standards. In many instances FM has a corresponding data sheet. FM Loss Prevention Data Sheets will generally take precedence.

2.1.4 Listed or Approved

Within the NFPA Standard, Listed means equipment approved by FM Approvals and listed in the *Approval Guide*, publication of FM Approvals.

Within the NFPA Standard, Approved means acceptable to the Factory Mutual Insurance Company. FM Approved equipment should be used whenever possible.

2.2 Comments and Exceptions

Carbon dioxide extinguishing systems use either high-pressure storage containers (i.e., cylinders at room temperature — typically 50, 75, 100 or 120 lb capacity and 30 or 50 kg capacity) or low-pressure storage containers (i.e., large refrigerated tanks – ¾ ton [200 kg] or larger). For further clarification, see pressure, high and pressure, low definitions under Section 1-3 and also Sections 1-9.5 and 1-9.6 entitled ''High-Pressure Cylinders'' and ''Low-Pressure Storage Containers'', respectively, of NFPA 12. System storage container selection is primarily based on economics, which is strongly influenced by hardware requirements. Typically, selecting a low-pressure storage container becomes more favorable as system carbon dioxide requirements increase. Multiple timed discharges are also possible with low-pressure storage containers.

The following comments provide FM interpretations of specific sections, identified by paragraph number, of the 2000 Edition of NFPA 12.

1-5.1 — Reducing the oxygen content from the normal 21% in air to 15% will extinguish most fires. For some materials, however, it must be reduced to 6% or less. Cooling effect is of little significance.

1-6.1 — When total flooding systems are used, a predischarge alarm and time delay are provided to permit evacuation of personnel before the actual discharge. See 1-6.1.1 and 1-6.1.4 for further guidance. System discharge should be as prompt as possible while satisfying the guidelines of 1-6.1.4. Local application systems can also present personnel exposure concerns where the hazard being protected is located in a confined space or area, or low spaces or areas are nearby. In evaluating whether any personnel exposure potential exists with a local application system, assume one lb (0.45 kg) of carbon dioxide yields 8 ft^3 (225 dm^3) of carbon dioxide gas.

1-6.1.7 –

1. Use a manually operated lockout such as a valve or disconnect of the activation mechanism while work is performed in an area protected by a carbon dioxide system. Software lockouts or software bypasses on microprocessor based control panels should not be considered effective in preventing discharge of an extinguishing system controlled by the panel.

2. Report system impairments to the local FM office so that appropriate precautionary guidance may be obtained. Follow procedures based on the use of the FM Red Tag Procedure.

3. Provide labels on microprocessor based panels warning that software lockout or bypass is not a safe means of preventing actuation of carbon dioxide systems.

1-7.3 (d)/1-7.4 — After installation of a carbon dioxide system, conduct a turnover test as described under Approval of Installations (Acceptance Testing) in Data Sheet 4-0, *Special* Protection Systems.

For high-pressure systems, discharge sufficient gas to insure proper operation of all system components.

In low-pressure systems, only sufficient carbon dioxide need be discharged to measure the time to reach equilibrium flow. Allow the timer to complete its cycle to determine that the proper discharge time at equilibrium flow is provided.

Where conditions involving total flooding systems make it difficult to predict the adequacy of design methods, conduct a complete system discharge to make certain that the design concentration is attained within the specified time limit.

Conduct a concentration test for carbon dioxide systems protecting rotating electrical equipment of 3000 kVa or 2500 hp (1865 kW) and over, or smaller units that are important to production with equipment at full speed when the system is actuated. Where several similar units of totally enclosed rotating electrical equipment have identical carbon dioxide needs, a satisfactory concentration test for the unit with the greatest gas leakage is sufficient. The unit of greatest leakage may be determined by discharging enough gas into each one and operating at normal speed to obtain a concentration reading and then to compare the rates at which the concentrations drop.

Conduct a concentration test discharge for total flooding systems in which additional compensating gas of 10% or more is provided.

Take gas samples above the highest point of flammable occupancy. Where the hazard occupies an entire enclosure as with rotating electrical equipment, locate the sample point at the highest possible part of the hazard and in no case below the center line of a rotating shaft

1-8.2 — Refer to the appropriate FM occupancy data sheet, as applicable, for guidance on detection system(s) selection and arrangement.

1-8.5.3 — Predischarge and discharge alarms, and trouble signals should be both audible and visual.

1-8.6 — The primary power supply should be independent of the power supply for the hazard area and should not be exposed by the hazard area. Wiring in the protection area should be either mineral insulated or in conduit. An emergency battery-powered supply, as required for an FM Approved control panel, is an acceptable secondary (standby) power supply.

1-9.1.2 — One reserve supply is sufficient. Provide a connected reserve for any system protecting more than one hazard through selector valves. Also provide a connected reserve where the carbon dioxide system is sole protection unless rechargeable within 24 hours or otherwise specifically recommended in the appropriate FM occupancy data sheet.

1-9.1.3 — See FM comment under 1-9.1.2.

1-9.2 — See FM comment under 1-9.1.2.

1-9.6.2 — In addition to the recommended high-low pressure supervisory alarm, lock and supervise in the open position the manual tank shutoff valve and the vapor supply line valve where provided.

1-10.2. — Avoid unnecessarily exposing supply piping to high temperatures from ovens or furnaces or to direct flame impingement prior to discharge. Hot piping causes excessive vaporization of carbon dioxide and resultant delay in effective discharge.

1-10.3.4 — Equivalent lengths for valves, cylinder connections and other equipment are provided in Chapter 5 – Fixed Extinguishing Systems of the Fire Protection Section of the *Approval Guide* for each equipment manufacturer under the heading Carbon Dioxide Systems. Equivalent lengths of pipe fittings are given in Tables A-1-10.5 (d) and A-1-10.5 (e).

1-10.4.5 – Provide Approved nozzle protective devices where needed and check their condition weekly. For further guidance, refer to the Nozzles Section (2.1.3.6) of Data Sheet 4-0, *Special Protection Systems*.

1-10.5.1 – This equation is the basis of the curves provided in the Carbon Dioxide Flow Charts (no longer in print) which were used to design and calculate carbon dioxide systems. Carbon dioxide system manufacturers now use flow calculation programs that are based on this equation and the flow charts.

1-11.3.4 – Conduct weekly inspections to check that nozzles are clear and in proper position, that all operating controls are properly set, and that components have not been damaged or altered.

1-11.3.8 — Report any impairment to the local FM office so that appropriate precautionary guidance may be obtained. Follow procedures based on the use of the FM *Red Tag Permit System*.

2-2.3.2 — See 2-4.1 and A-2-4.1 and FM comment under A-2-4.1.

2-3.5.5 – Surface fires are extinguished by total flooding discharge as soon as the design concentration is reached. Holding this concentration increases the factor of safety. However, in most enclosures the concentration will remain for some time and no holding time is specified. See 2-5.2.1.

2-5.2.1 – In high-pressure systems, where delay in achieving equilibrium flow will be insignificant, the rate of discharge will be the recommended total quantity divided by one minute. In low-pressure systems, the delay time and amount of carbon dioxide vaporized in cooling the piping should be calculated and the equilibrium flow rate increased accordingly to deliver the desired quantity within one minute after discharge including delay time. Delay time and weight vaporized during this period may be calculated as follows:

English Units

Delay time (low-pressure systems):

$$Dt = \frac{w\,C_p(T_1 - T_2)}{0.913R} + \frac{1050\,V}{R}$$

Weight vaporized (low- or high-pressure systems):

$$W = \frac{w\,C_p(T_1 - T_2)}{H}$$

where Dt = delay time, sec
W = weight of carbon dioxide vaporized, lb
w = weight of piping, lb (see Table FM A-3-3.1.2)
C_p = specific heat of metal in pipe (0.11 for steel)
T_1 = average pipe temperature before discharge, °F
T_2 = average carbon dioxide temperature, °F
Note: Assume 60°F for high pressure and −5°F for low pressure under normal conditions
R = system design flow rate, lb/min
V = volume of piping, ft^3 (see Table FM A-3-3.1.2)
H = latent heat of vaporization of liquid carbon dioxide, Btu/lb.
Note: About 64 Btu/lb for high-pressure and about 120 Btu/lb for low-pressure systems.

Metric Units

Delay time (low-pressure systems):

$$Dt = \frac{w\,C_p(T_1 - T_2)}{0.507R} + \frac{16830\,V}{R}$$

Weight vaporized (low- or high-pressure systems):

$$W = \frac{w\,C_p(T_1 - T_2)}{H}$$

where Dt = delay time, sec
W = weight of carbon dioxide vaporized, kg
w = weight of piping, kg (see Table FM A-3-3.1.2)
C_p = specific heat of metal in pipe (0.11 for steel)
T_1 = average pipe temperature before discharge, °C
T_2 = average carbon dioxide temperature, °C
Note: Assume 15.6°C for high pressure and -20.6°C for low pressure under normal conditions
R = system design flow rate, kg/min
V = volume of piping, m^3 (see Table FM A-3-3.1.2)
H = latent heat of vaporization of liquid carbon dioxide.
Note: About 35.5 kcal/kg for high-pressure and about 66.6 kcal/kg for low-pressure systems.

3-2.2 – Carbon dioxide protection is generally not recommended for hazards located out of doors.

3-3.2.2/3-3.2.3 – When the quantity of carbon dioxide needed for the local application part is very small as compared with the total flooding part, it may be more practical to extend the discharge time of the local application part to that of the total flooding part by providing additional carbon dioxide.

3-3.3.2 – Carbon dioxide has very little cooling capacity and other extinguishing agents should be considered for any hazards involving such fuels. Wet chemical or fine water spray should be considered for cooking oil hazards. Fine water spray should be considered for hazards involving paraffin wax.

A-1-8.3.6 – See Figure FM A-1-8.3.6.

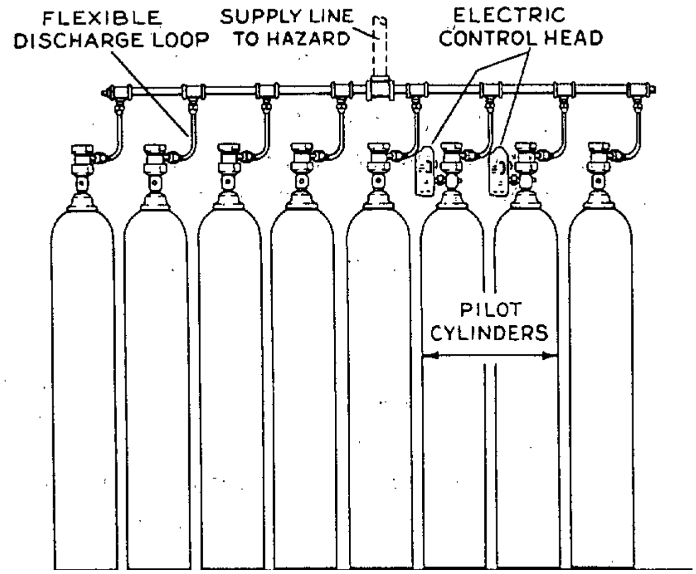
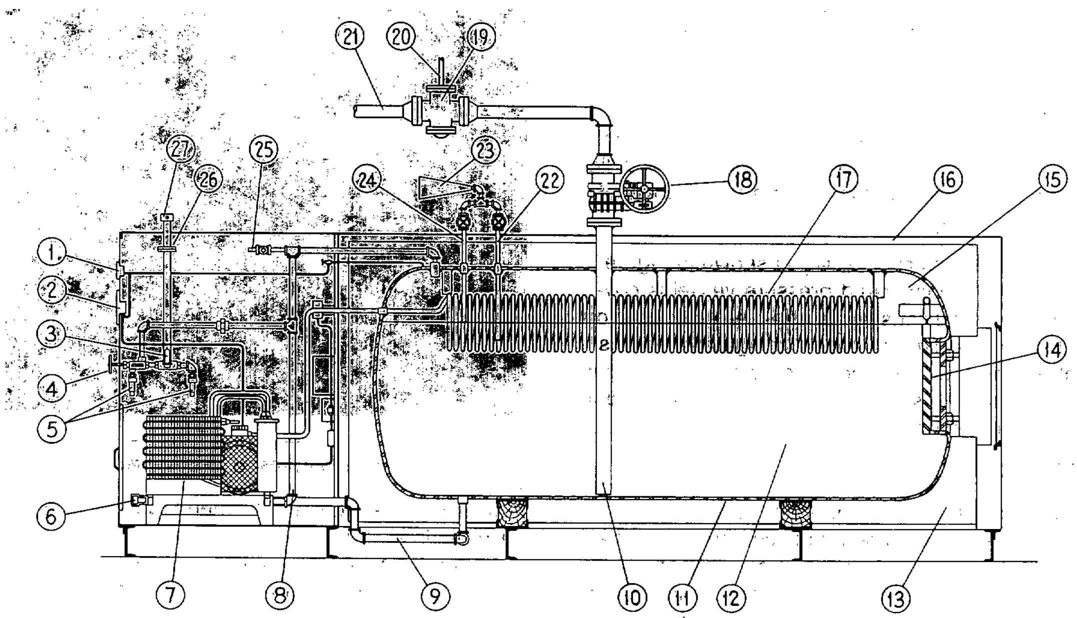


Fig. FM A-1-8.3.6 Typical cylinder arrangement for high-pressure system.

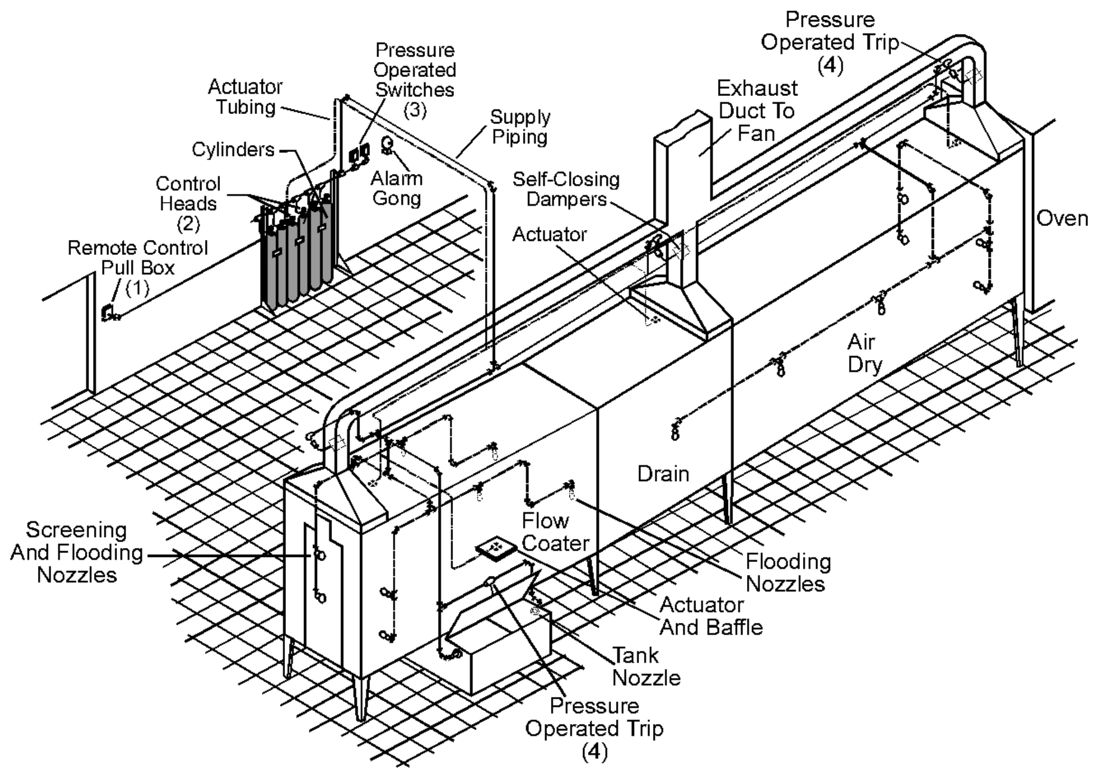
A-1-9.6 — See Figure FM A-1-9.6.



1. Carbon dioxide pressure gage
2. Carbon dioxide liquid-level gage
3. Bleeder relief valve, 341-lb diaphragm type
4. Pressure-relief-valve selector
5. Pressure-relief valves, 357-lb spring-loaded type
6. Carbon dioxide filling connection
7. Refrigerating unit
8. Carbon dioxide vapor-equalizing pipe
9. Carbon dioxide liquid-filling pipe
10. Dip tube
11. Pressure vessel, ASME Code
12. Carbon dioxide liquid
13. Insulation, 5-in. cork
14. Manway cover
15. Carbon dioxide vapor
16. Sheet-metal outer casing
17. Cooling coil
18. Manual shutoff valve
19. Master discharge valve
20. Carbon dioxide gas-pressure pipe from discharge control
21. Carbon dioxide supply pipe to selector valves
22. 90 per cent carbon dioxide liquid-content check tube with control valve
23. Discharge test horn for checking carbon dioxide liquid content
24. 100 per cent carbon dioxide liquid-content check tube with control valve
25. Carbon dioxide gas-pressure supply pipe to discharge control
26. Pressure relief, 600-lb frangible-disk type
27. Pressure-relief vent to atmosphere

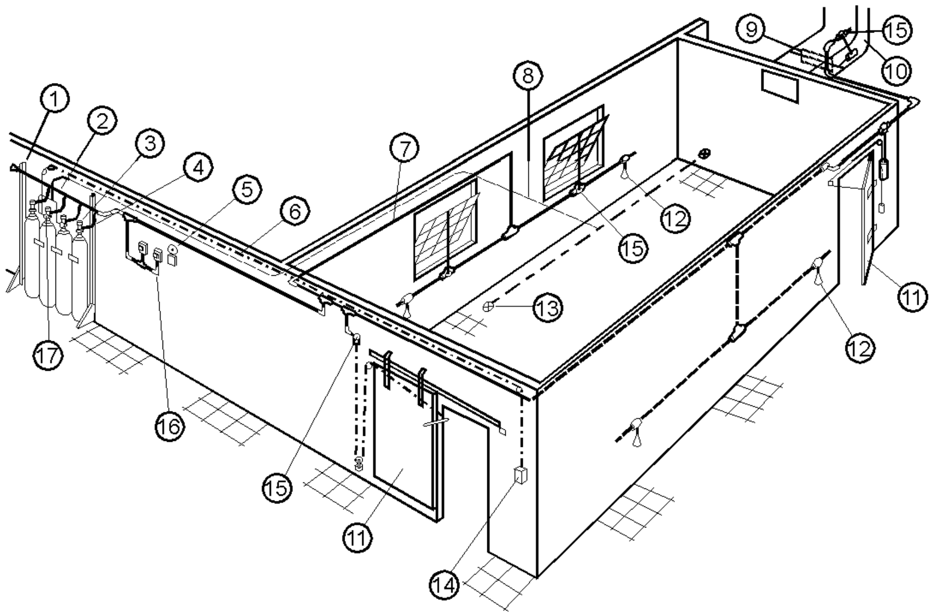
Fig. FM A-1-9.6 Refrigerated low-pressure storage unit.

A-2-1 – Typical total flooding system examples are shown in Figures FM A-2-1(a) and FM A-2-1(b).



1. Normal manual pull box control and cable
2. Pneumatic control heads with emergency manual controls
3. Pressure-operated switches to shut down exhaust fan, pumps, conveyor, etc., and sound alarm
4. Pressure-operated trips to release self-closing dampers in exhaust duct and self-closing cover on paint tank

Fig. FM A-2-1(a) Typical total flooding system for paint flow-coater machine.



1. Cylinder framing
2. Cylinder manifold
3. Pressure-operated discharge head
4. Flexible connection
5. Alarm gong
6. Remote-control cable 1/16-in. (1.6-mm), run in 3/8-in. (9.5-mm) galvanized pipe or conduit with corner pulleys at all changes in directions; no bends or offsets allowed
7. Carbon dioxide piping
8. Actuator tubing, run in 1/2-in. (13-mm) conduit
9. Self-closing weight-operated damper
10. Air-exhaust duct
11. Fire door
12. Nozzle
13. Actuator on ceiling
14. Remote-control pull box
15. Pressure-operated trip to release self-closing damper, fire doors, and windows
16. Pressure-operated switches to sound alarm and shut down fan
17. Pneumatic-control head with local manual control

Fig. FM A-2-1(b) Typical total flooding system for enclosed room.

A-2-4.1 – The holding time for fur and record vaults and closely packed combustible materials that will tend to smolder is 30 minutes. Enclosures should not be opened for examination and salvage until the end of the holding period. Suitable placards at the hazard should show the recommended holding time.

A-3-1.2 – A typical local application system example is shown in Figure FM A-3-1.2.

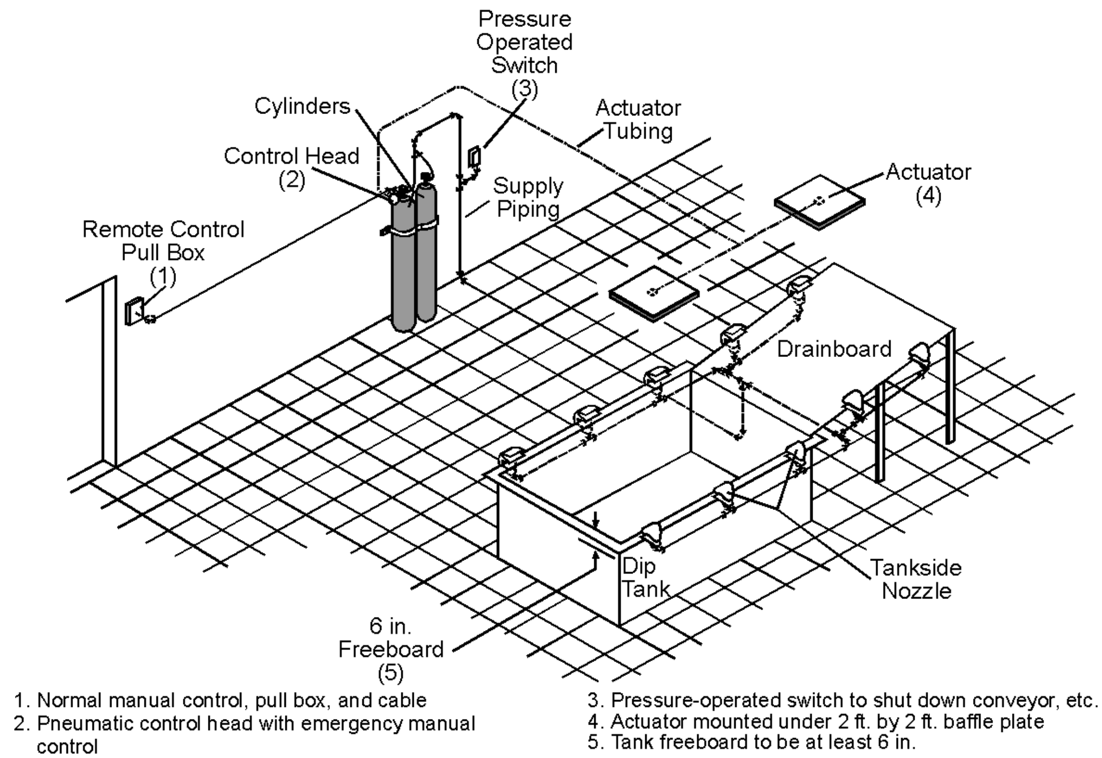


Fig. FM A-3-1.2 Typical local-application system for dip tank and drainboard.

A-3-3.1.2 – See Table FM A-3-3.1.2 for weights of steel piping.

Table FM A-3-3.1.2 Weights and Volumes of Steel Pipe

Nominal Pipe Size		*Schedule 40*				*Schedule 80*			
		Weight		*Volume*		*Weight*		*Volume*	
in.	*(mm)*	*lb/ft*	*(kg/m)*	*ft^3/ft*	*(m^3/m)*	*lb/ft*	*(kg/m)*	*ft^3/ft*	*(m^3/m)*
½	*13*	*0.85*	*(1.23)*	*0.0021*	*(0.00019)*	*1.08*	*(1.56)*	*0.0016*	*(0.00015)*
¾	20	1.13	(1.64)	0.0037	(0.00034)	1.47	(2.13)	0.003	(0.00028)
1	25	1.68	(2.43)	0.006	(0.00056)	2.17	(3.14)	0.005	(0.00046)
1¼	32	2.27	(3.29)	0.010	(0.00093)	3.00	(4.34)	0.009	(0.00084)
1½	40	2.72	(3.94)	0.014	(0.00130)	3.63	(5.26)	0.012	(0.00111)
2	50	3.65	(5.29)	0.023	(0.00214)	5.02	(7.27)	0.021	(0.00195)
2½	65	5.79	(8.39)	0.033	(0.00306)	7.66	(11.09)	0.029	(0.00269)
3	80	7.58	(10.98)	0.051	(0.00474)	10.25	(14.84)	0.046	(0.00427)
3½	90	9.11	(13.19)	0.068	(0.00631)	12.50	(18.10)	0.062	(0.00576)
4	100	10.79	(15.63)	0.088	(0.00817)	14.98	(21.69)	0.080	(0.00743)
5	125	14.62	(21.17)	0.139	(0.01291)	20.78	(30.09)	0.126	(0.01170)
6	150	18.97	(27.47)	0.201	(0.01866)	28.57	(41.38)	0.181	(0.01681)

Appendix B, B-1 Commercial/Industrial Food Processing Deep-Fat (Hot Oil) Cookers — Protection of industrial oil cookers is covered by FM Loss Prevention Data Sheet 7-20, *Oil Cookers*. Carbon dioxide protection of industrial oil cookers is not recommended by FM given the limited cooling capacity of carbon dioxide and its questionable effectiveness based on reported loss experience.

Appendix B, B-3 Newspaper Printing and Rotogravure Presses – Protection of printing presses is covered by Data Sheet 7-96, *Printing Plants*. Design guidance included under this section may be used where carbon dioxide extinguishing systems are provided for protection of newspaper, rotogravure, and similar presses.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 General

Satisfactory performance of a carbon dioxide extinguishing system can best be assured by following the loss prevention guidance provided within this document.

FM comment under 1-6.1.7 was added as a consequence of a fatal accidental carbon dioxide extinguishing system discharge at a U.S. Department of Energy (DOE) site, Idaho National Engineering and Environmental Laboratory, in July 1998. A software lockout on the system control panel was used to deactivate the actuation circuit for the carbon dioxide system. However, the carbon dioxide system accidentally discharged without warning due to a control panel malfunction while personnel were conducting maintenance on electrical switchgear within the protected area.

4.0 REFERENCES

4.1 FM

Data Sheet 4-0, *Special Protection Systems*

Data Sheet 7-20, *Oil Cookers*

Data Sheet 7-96, *Printing Plants*

4.2 NFPA

NFPA 12, *Standard for Carbon Dioxide Extinguishing Systems*, 2000 Edition.

4.3 Other

ISO 6183:1990, Fire Protection Equipment – Carbon Dioxide Extinguishing Systems for Use on Premises – Design and Installation.

APPENDIX A DOCUMENT REVISION HISTORY

January 2013 (Interim revision). Minor editorial changes were made for this revision.

April 2011. Minor editorial changes were made for this revision.

September 2010. Minor editorial changes were made for this revision.

May 2003. This data sheet supersedes the January 2000 edition of Data Sheet 4-11N. The previous version of this data sheet was based on the 1989 Edition of NFPA 12. This previous version of the data sheet was editorially revised/reformatted in September, 1998. Appendix D, Support for Recommendation, was added in January 2000 in support of an FM Global comment under 1-6.1.7 to provide a manually operated lock-out and not a software lock-out to prevent accidental actuation of a carbon dioxide system. Appendix D has been deleted from this data sheet but support for the FM Global comment under 1-6.1.7, which remains, is summarized under Section 3.0 ''Support for Recommendations''.

The 2000 edition of NFPA 12 was revised to include requirements for carbon dioxide systems for marine applications (Chapter 6) and to provide guidance on lock-outs (1-3.7, 1-6.1.7, 1-8.4 and A-1-6.1.7) and carbon dioxide system design for below raised floors (Appendix B, B-5). Other revisions of NFPA 12 since the 1989 Edition include a 1993 Edition and a 1998 Edition. The 1993 Edition of NFPA 12 was a complete rewrite of the 1989 Edition to make the document more useable, enforceable and adoptable (i.e., clearly state the requirements separating the mandatory requirements from the advisory text). The 1998 Edition of NFPA 12 was revised to include guidance for safe handling of cylinders (1-5.1.8 and A-1-5.1.8) and sound levels for audible system predischarge alarms (1-7.5). Carbon dioxide system design guidance for protection of industrial oil cookers was also added (Appendix B, B-1) which conflicts with FM Global guidance (See applicable FM Global comment under Section 2.2 of this data sheet for further clarification). This data sheet is now a separate document to be used with the 2000 Edition of NFPA 12.

September 1993. The 1993 version of Data Sheet 4-11N was editorially revised in September 1998 reformatting the document in accordance with the new structure for data sheets. In January 2000, an FM Global comment was added under paragraph 1-6.1.7 of the NFPA 12 text advising against carbon dioxide system software lock-outs with supporting information provided as FM Global Appendix D.

January 1993. Data Sheet 4-11N was created in 1993, including the exact text of NFPA 12 1989 Edition, appendix material, and the applicable FM Global comments in bold letters (replaced Data Sheet 4-11 dated July 1976).